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INFLUENCE OF DECK PLATING STRENGTH ON SHIP HULL ULTIMATE BENDING MOMENT

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PURPOSE OF THE STUDY

The analysis was performed to find f_β coefficient values dependent on deck plating thickness.
The sagging and hogging ultimate bending moments were computed for various ship types.
The computations were performed applying a PRS elaborated computer program *Naprężenia.exe*
The application calculates ultimate bending moments for a steel hull.
Computations account for a 3D ship hull segment of fixed length l. for sagging and hogging of the segment in the user defined range $[\chi_p, \chi_k]$ of the curvature χ.
The program:

- reads ship structure data describing ship hull transverse cross section,
- creates or modifies the elements of ship's hull transverse cross-section for which $\sigma - \varepsilon$ curves are used,
- calculates the maximum bending moment M which can be equilibrated by normal stresses in the cross-section,
- computes maximum hull bending moment M,
- gives the curvature χ corresponding to maximum bending moment M,
- gives curvature value χ in the specified range $[\chi_p, \chi_k]$ when the maximum is reached,
- gives coordinate z_0, of the neutral axis in succeeding steps of computations provided the t the longitudinal force in the cross-section is close to zero,
- determines coordinate z_0, of the neutral axis for longitudinal force close to zero, and
- generates diagrams of computed values and an animation showing changes of the computed values as a function of χ.

The report presents computation results of f_β in the equation:

$$\gamma_s M_{sw} + f_\beta \gamma_w M_{wv} = M_{Ult} / \gamma_R$$

where:
M_{sw} – still water bending moment (hogging or sagging),
M_{wv} – ave bending moment (hogging or sagging),
M_{ult} – ultimate bending moment.
Partial safety factors γ_R and γ_w are assumed according to the requirements of IACS Common Structural Rules for Bulk Carriers and Oil Tankers (January 2015) given in Chapter 5, Section 2. These values are given in Table 1.

Table 1. Partial safety factors

		γ_S	γ_W	γ_{DB}	γ_M	$\gamma_R=\gamma_{DB}*\gamma_M$
Bulk carrier	**hogging**	1.0	1.2	1.25	1.1	1.375
	sagging	1.0	1.2	1.0	1.1	1.1
Oil Tanker	**hogging**	1.0	1.2	1.1	1.1	1.21
	sagging	1.0	1.2	1.0	1.1	1.1

Symbols in Table 1 have the meaning:

- γ_S – partial safety factor for still water bending moment;
- γ_W – partial safety factor for the vertical wave bending moment;
- γ_R – partial safety factor for the vertical hull girder ultimate bending moment;
- γ_M – partial safety factor for the vertical hull girder ultimate bending capacity covering material, geometric and strength prediction uncertainties;
- γ_{DB} – partial safety factor for the vertical hull girder ultimate bending capacity covering the effect of double bottom bending.

1. 80000 DWT BULK CARRIER

1.1 SHIP MAIN DATA

The data are given in Table 2.

Table 2. Main data of bulkcarrier I

Hull length	L = 218.83 m
Length between perpendiculars	L_{PP} = 222.00 m
Moulded breadth of ship	B = 32.26 m
Moulded depth of ship	D = 20.25 m
Scantling draught	T_{SC} = 14.62 m
Block coefficient at draught *Tsc*	C_B = 0.879

1.2 STILL WATER AND WAVE BENDING MOMENTS

Still water bending moment values $M_{sw\text{-}s}$, $M_{sw\text{-}h}$, $M_{wv\text{-}s}$, $M_{wv\text{-}h}$, for intact condition were computed according to CSR requirements (Chapter 4, Section 4). Their values are given in Table 3.

Table 3. Still water bending moments values in intact condition

Cargo hold	Fr.	*x/L* [–]	$M_{sw\text{-}s}$ kNm]	$M_{sw\text{-}h}$ [kNm]	$M_{wv\text{-}s}$ [kNm]	$M_{wv\text{-}h}$ [kNm]
CH4	142	0.54	–1750000	2170000	–2699366	2595624

1.3 SECTION MODULUS VALUE OF THE HULL IN MIDSIP HOLD REGION

The cross-section in hold No. 4 is schematically shown in the figure below.
Computed transverse cross section area *As*, inertia bending moment $Izz = I_{y\text{-}n50}$ and neutral axis coordinate *zg*, for cargo hold No. 4, read:
As = 33062.22 cm^2, Izz = 230.5566 m^4, zg = 8.5551 m.

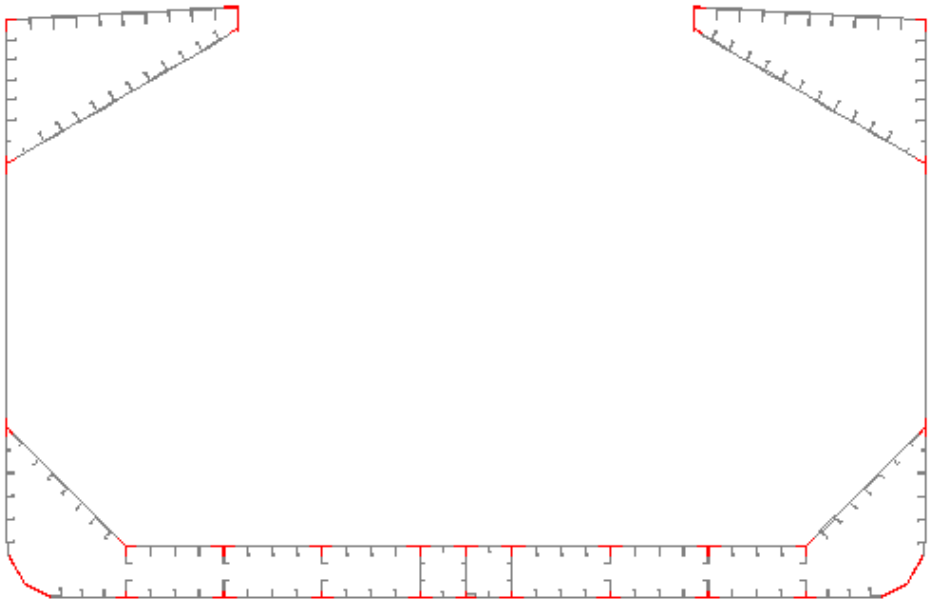

Fig. 1. Ship hull cross-section at cargo hold No. 4

1.4 ULTIMATE BENDING MOMENT

Computations were performed for some strength deck plating values. The deck thickness in the computations was decreased by $0.5t_c$ to 22 mm (the 'offered' deck thickness was 24 mm). Yield stress R_{eH} = 355 MPa.

Values of f_β computed for the bending moments values given in Table 3 are given in Table 4 and in diagrams shown in Fig.1.

Table 4. Ultimate bending moment and f_β values

Deck thickness [mm] *t*-0.5*tc*	$M_{ULT\_sagging}$ [kNm]	$M_{ULT\_hogging}$ [kNm]	$f_{\beta\_}$ sagging	f_β hogging
12	5 872 581	7 213 206	1.11	1.22
13	6 003 645	7 303 089	1.14	1.24
14	6 136 796	7 390 570	1.18	1.26
15	6 277 743	7 476 235	1.22	1.29
16	6 414 127	7 560 228	1.26	1.31
17	6 552 237	7 642 875	1.30	1.33
18	6 695 703	7 723 982	1.34	1.35
22	**7 248 463**	**8 035 638**	**1.49**	**1.44**
23	7 383 046	8 110 156	1.53	1.46
24	7 512 488	8 183 871	1.57	1.47
25	7 645 629	8 256 026	1.61	1.49
26	7 773 388	8 326 450	1.64	1.51
27	7 895 639	8 394 570	1.68	1.53
32	8 478 852	8 670 547	1.84	1.60

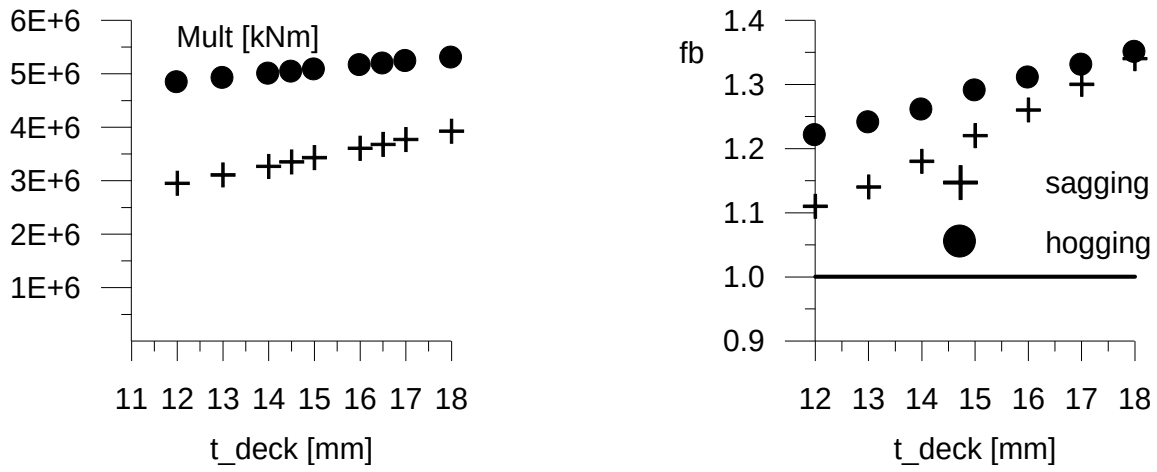

Fig. 2. Ultimate bending moment and f_β values as function of deck thickness

- **Hull girder ultimate strength**

Appraisal of the ship ultimate strength according to the requirements of the present CSR and the proposal to increase the wave bending moment design value by 5%, is given in Table 5 where:

$$M = \gamma_s M_{sw} + f_\beta \gamma_w M_{wv}$$

Table 5. Requirements for hull girder ultimate strength

Operation		**Seagoing**	**Seagoing**
Condition		**Hogging**	**Sagging**
γ_R		1.375	1.1
M_{sw} [kNm]		2170000	1750000
M_{wv} [kNm]		2595624	2699366
M	CSRH [kNm]	5284749	5019239
	1.05 CSRH [kNm]	5440486	5181201
	1.05 CSRH/CSRH [%]	102.9%	103.2%
M_U	[kNm]	8035638	7248463
$M_U/\gamma_R/M$	CSRH [%]	110.6%	131.3%
	1.05 CSRH [%]	107.4%	127.2%

- **Hull girder strength**

Appraisal of the ship hull girder strength according to the requirements of present CSR and the proposal to increase the wave bending moment design value by 5%, is given in Table 6.

Table 6. Requirements to Section Modulus

Operation		**Seagoing**	**Seagoing**
Condition		**Hogging**	**Hogging**
M_{sw} [kNm]		2170000	2170000
M_{wv}	CSRH [kNm]	2595624	2595624
	1.05 CSRH [kNm]	2725405	2725405
	1.05 CSRH/CSRH [%]	105.0%	105.0%
Z_{required}	CSRH [m^3]	18.06	18.06
	1.05 CSRH [m^3]	18.61	18.61
	1.05 CSRH/CSRH [%]	103.0%	103.0%
Z_{actual} [m^3]		19.54	26.4
$Z_{\text{actual}}/Z_{\text{required}}$	CSRH [%]	108%	146%
	1.05 CSRH [%]	105%	142%

2. 30000 DWT OIL TANKER

2.1 SHIP MAIN DATA

The data are given in Table 7.

Table 7. Ship main data

Hull length	L = 168.18 m
Length between perpendiculars	L_{PP} = 168.18 m
Moulded breadth of ship	B = 25.30 m
Moulded depth of ship	D = 18.00 m
Scantling draught	T_{SC} = 11.35 m
Block coefficient at draught *Tsc*	C_B = 0.820

2.2 STILL WATER AND WAVE BENDING MOMENTS

Still water bending moment and wave bending moments values $M_{sw\text{-}s}$, $M_{sw\text{-}h}$, $M_{wv\text{-}s}$, $M_{wv\text{-}h}$, for intact conditions were computed according to CSR requirements (Chapter 4, Section 4). Their values are given in Table 8.

Table 8. Bending moment values

Cargo hold	x/L [–]	$M_{sw\text{-}s}$ [kNm]	$M_{sw\text{-}h}$ [kNm]	$M_{wv\text{-}s}$ [kNm]	$M_{wv\text{-}h}$ [kNm]
CH4	0.57	–1648521	1725783	–1107277	1030015

2.3 SECTION MODULUS VALUE OF THE HULL IN MIDSHIP HOLD REGION

CARGO HOLD NO. 4

The cross-section in the midship is schematically shown in the figure below.
Computed transverse cross section area *As*, inertia bending moment $Izz = I_{y\text{-}n50}$ and neutral axis coordinate *zg*, for cargo hold No. 4, read:
As = 25249.4 cm^2, Izz = 125.93 m^4 , zg = 7.287 m.

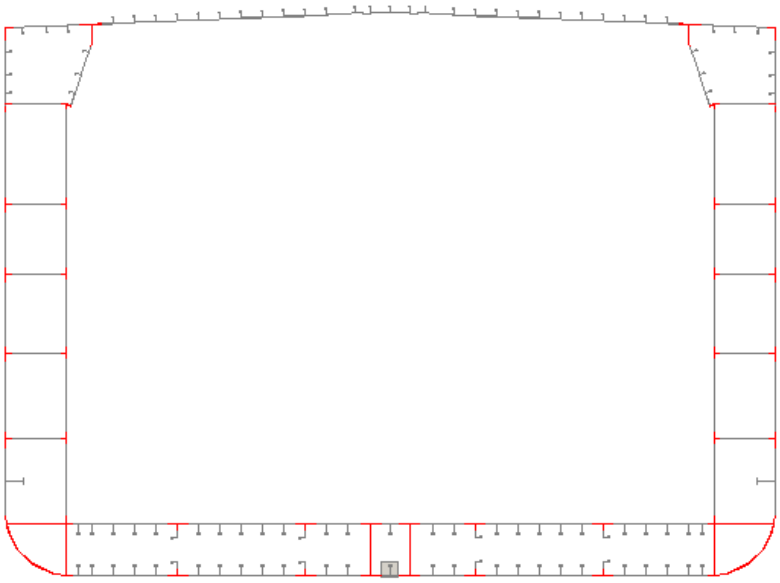

Fig. 3. Ship hull cross-section at cargo hold No. 4

2.4 ULTIMATE BENDING MOMENT FOR TANKER HULL

The computations were performed for some strength deck plating values. The deck thickness in the computations was decreased by $0.5t_c$ to 12 mm (the 'offered' deck thickness was 14 mm). Yield stress R_{eH} = 315 MPa.

Values of f_β computed for the bending moments given in Table 8 are given in Table 9 and in diagrams shown in Fig. 4.

Table 9. Ultimate bending moment and f_β values

Thickness [mm] $t - 0.5tc$	$M_{ULT\_sagging}$ [kNm]	$M_{ULT\_hogging\|}$ [kNm]	$f_{\beta\_}$ sagging	f_β hogging
12.00	**2 950 616**	**4 830 730**	**0.78**	**1.83**
13.00	3 107 498	4 912 228	0.89	1.89
14.00	3 267 560	4 991 626	0.99	1.94
14.50	3 348 853	5 031 395	1.05	1.97
15.00	3 429 969	5 071 215	1.11	1.99
16.00	3 604 578	5 151 344	1.23	2.05
16.50	3 677 144	5 183 202	1.28	2.07
17.00	3 769 888	5 226 772	1.34	2.10
18.00	3 924 330	5 294 039	1.44	2.14
19.00	4 088 229	5 364 420	1.56	2.19
22.00	4 572 769	5 552 207	1.89	2.32

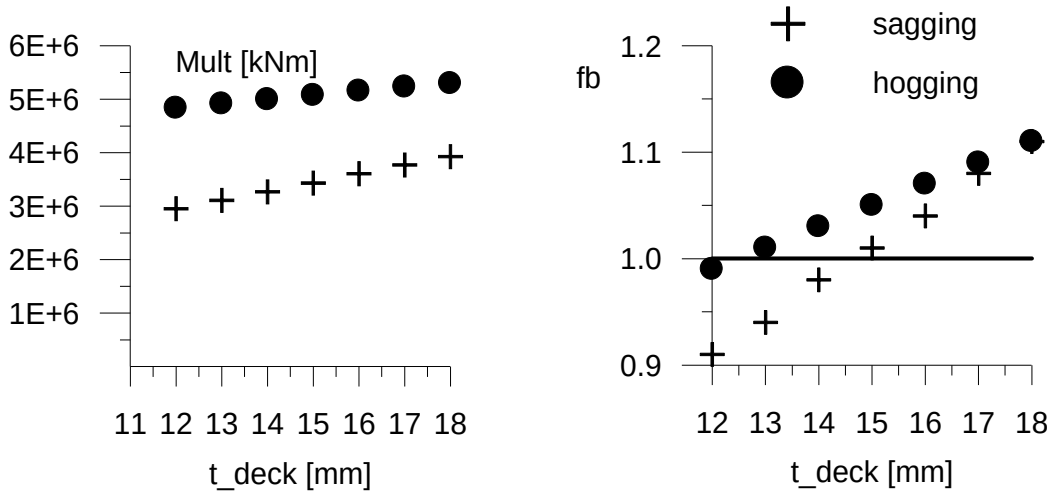

Fig. 4. Ultimate bending moment and f_β values as function of deck thickness

3. BULK CARRIER No. 2

3.1 SHIP MAIN DATA

The data are given in Table 10.

Table 10. Ship main data

Hull length	L = 281.95 m
Length between perpendiculars	L_{PP} = 282 m
Moulded breadth of ship	B = 44.2 m
Moulded depth of ship	D = 24.99 m
Scantling draught	T_{SC} = 18.442 m
Block coefficient at draught Tsc	C_B = 0.8095

3.2 STILL WATER AND WAVE BENDING MOMENTS IN INTACT CONDITION

Still water bending moments $M_{sw\text{-}s}$, $M_{sw\text{-}h}$, $M_{wv\text{-}s}$, $M_{wv\text{-}h}$, for intact conditions were computed according to CSR requirements (Chapter 4, Section 4). Their values are given in Table 11.
Still water and wave bending moments $M_{sw\text{-}s}$, $M_{sw\text{-}h}$, $M_{wv\text{-}s}$, $M_{wv\text{-}h}$ for ship in intact condition:

Table 11. Still water and waving bending moments in in tact condition

Cargo hold	x/L [-]	$M_{sw\text{-}s}$ [kNm]	$M_{sw\text{-}h}$ [kNm]	$M_{wv\text{-}s}$ [kNm]	$M_{wv\text{-}h}$ [kNm]
CH4	0.57	–3 658 159	4 007 365	–6 238 504	5 768 146

3.3 SECTION MODULUS VALUE OF THE HULL IN MIDSIP HOLD REGION

The cross-section in hold No. 4 is schematically shown in Fig. 5 below.
Computed transverse cross section area As, inertia bending moment $Izz = I_{y\text{-}n50}$ and neutral axis coordinate zg, for cargo hold No. 4, read:
As = 2* 30033.95 cm^2, Izz = 2*299.6143 cm^4, zg = 10.4847 m.

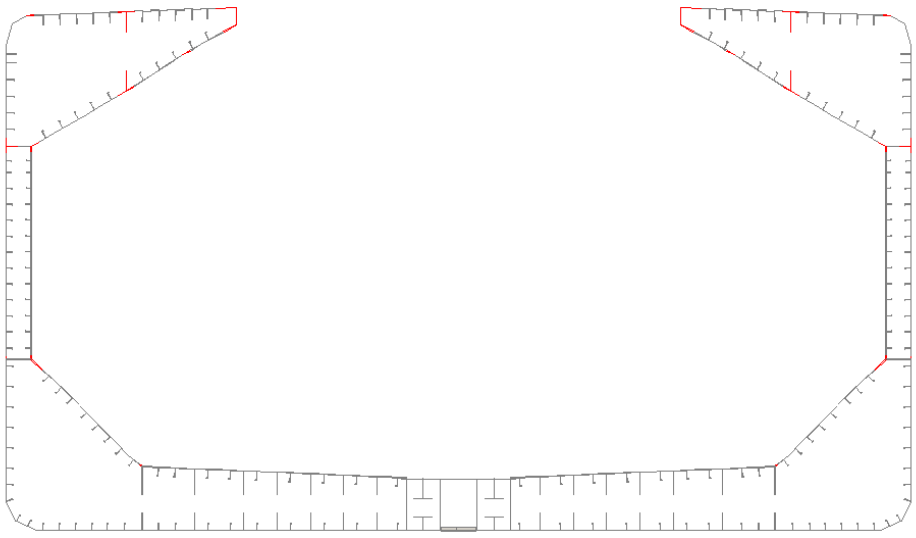

Fig. 5. Ship hull cross-section at cargo hold No. 4

3.4 ULTIMATE BENDING MOMENT FOR BULKCARRIERS

The computations were performed for some strength deck plating values. The deck thickness was decreased by $0.5t_c$ to 27 mm (the' offered' deck thickness was 29 mm). Yield stress R_{eH} = 315 MPa. Values of f_β computed for the bending moments given in Table 11 are given in Table 12 and in diagrams shown in Fig. 6.

Table 12. Ultimate bending moment and f_β values

Thickness [mm] $t - 0.5tc$	$M_{ULT\_sagging}$ [kNm]	$M_{ULT\_hogging}$ [kNm]	$f_{\beta\_}$ sagging	f_β hogging
27	14177852	13570109	**1.233**	**0.847**
28	14355953	13681130	**1.255**	**0.859**
40	16512221	14961760	**1.517**	**0.993**
44	15632028	15384590	**1.410**	**1.038**
46	17627483	15573682	**1.652**	**1.057**

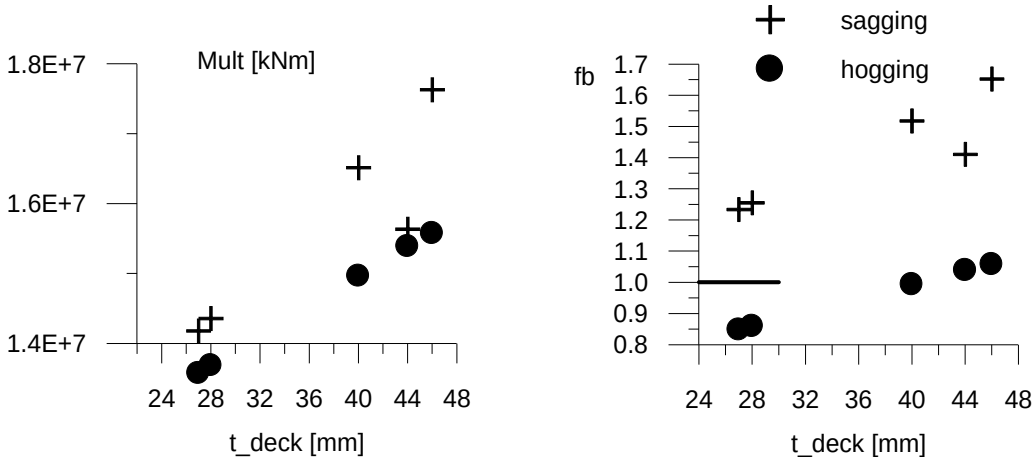

Fig. 6. Ultimate bending moment and f_β values as function of deck thickness

Bibliography

1. Common Structural Rules for Bulk Carriers and Oil Tankers, July 2015.